On the Phonological Interpretation of Vowel Reduction: The Case of Russian and Catalan

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ABSTRACT

From a collection of preliminary experimental data on the quality of some reduced vowels in Russian and Catalan, we explore the plausibility of the hypothesis that the output of such phonological processes as vowel reduction is better understood as underspecified, leaving to phonetic implementation the eventual determination of the actual quality of the reduced vowel.

1 INTRODUCTION

This paper is an attempt to explore some of the consequences that phonetic data may have, when taken into account in the interpretation of phonological processes, very much in the tradition of earlier discussions about the relation between phonological/phonetic representation and the processing of speech ([1], [2]).

Our target process is vowel reduction (henceforth VR) in Russian and Catalan. Both languages present the typical pattern of VR languages, namely a stressed vowel inventory that is reduced to a two/three vowel system for unstressed positions. The differences between the two languages wrt their reduced systems are striking, however, with Russian showing a dual system, clearly depending on the nature of the consonant preceding the reduced vowel (palatalised vs. non-palatalised), and Catalan less so, with an apparent systematic pattern of VR, independent of the consonantal environment. Russian, moreover, has two degrees of reduction after non-palatasiled consonants, depending on the distance between the target vowel and the stressed syllable.

The traditionally accepted description of VR in Central Catalan is one where mid and low unrounded vowels ([a, e, ɛ]) surface as [ə] in unstressed environments, mid and high rounded vowels ([u, o, ɔ]) surface as [u], and [i] is vacuously reduced to itself ([3], [4]).[1] Standard Russian, on the other hand, systematically reduces its vowels to [i] after palatalised consonants, except [u] which remains unchanged; after non-palatalised consonants, however, [ɨ, e] reduce to [ɨ] and [u] to itself for both degrees of reduction, while [á, o] reduce to [a] (1st degree) or [ə] (2nd degree);[2] see [5] and [6].

It is often recognised that the term 'vowel reduction' is used to refer to a variety of different phenomena all sharing the net effect of altering the quality of two or more phonemic vowels when appearing in unstressed contexts ([6], [3]). As witnessed by the two examples of VR described here, this appears to be certainly the case, as several other factors apart from stress seem to conspire in the determination of the output vowel like consonantal environment, the rhythmic pattern of the language, and so on. Despite this recognised heterogeneity, a common feature shared by most analyses is that the output of the VR process is assumed to be a fully specified segment with well-defined properties; see [7], [6] for Russian, and [3] and [4] for Catalan.

Now, given a number of well-known experimental results demonstrating the importance of a series of contextual factors—like consonantal environment and duration—in the final realisation of vowels ([8], [9], also [1]), one may wonder to what an extent this assumption is motivated. In other words, nothing in the literature appears to contradict the alternative hypothesis that the output of the phonology is some underspecified vocalic segment or bundle of features whose final quality is eventually determined during phonetic implementation. In fact, there are a number of reasons to believe, as adduced, for example, by [9] in his studies of VCV coarticulation (also [1]), that the input to phonetic implementation is often better conceived of

[1] There is a large amount of variation among Catalan dialects with respect to VR; see references cited for a detailed description of VR in the Central and other varieties.

[2] We adopt here the accepted convention among most Western linguists to represent these vowels. Russian also presents some dialectal variation wrt VR. Our data come from the Contemporary Standard variety, which belongs to the Central-Southern group of dialects.

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as an underspecified bundle and that underspecification is only resolved at this level, a solution already hinted at by [10].

2 EXPERIMENTAL PROCEDURES

If the phonetic realisation of a reduced vowel is in some way going to be determined by contextual factors (if only partially), one would expect to find significant differences in the quality of such a vowel, depending on consonantal environment and, possibly, other factors as well. Thus, we restricted our attention to phonemic /a/ in both Russian and Catalan preceded only by dental, alveolar and palatal consonants (i.e., the phonological class of coronals). The absence from our sample of labials and velars is explained as an attempt to have the highest control as possible over coarticulatory effects, thus eliminating the expected effects due to tongue retraction in the articulation of velars and any unexpected effect due to the greater freedom of tongue position during the articulation of labials.

In order to test our hypothesis, we set up a corpus of words for both Catalan and Russian including /a/ and its reduced counterparts, which we recorded and analysed under the conditions described below.

2.1 CATALAN DATA

The corpus was constructed attending to the following conditions:

a. All words were trisyllabic.
b. All syllables were open.
c. The target vowel appeared in the second syllable.

To fulfill these conditions we selected a number of content word pairs showing the appropriate stress alternation. We chose verbal forms within the same paradigm such that, in one form, the second syllable would be stressed, and, in the other, the stressed syllable would be the third, thus ensuring that the full and reduced variants appeared systematically in the same context.

In order to examine the effect of consonantal context on the target vowel, the following consonants were chosen: [t̪], [d̪], [ʃ], [ʒ], [n], [ʎ]. For each consonantal context, two Catalan content words all owing to the aforementioned alternance between stressed and unstressed environments were used.

In total, the corpus was composed of 24 words, which were read twice by four male speakers as a list of carrier sentences containing the word. The final sample was thus composed of 48 items per speaker. All items in the corpus were processed with the speech analysis software Praat+. Waveform displays and broad-band spectrograms were plotted for each sequence, and measurements for vowel quality (F1, F2) and duration were taken.

2.2 RUSSIAN DATA

The most relevant differences between Catalan and Russian have to do with the fact that Russian has palatalised consonants and two degrees of vowel reduction. The corpus to be constructed had therefore to fulfill certain different conditions.

The consonants included were [t̪], [d̪], [n̪], [l̪], [ʃ] plus their palatalised counterparts, and different syllable positions with respect to stress were considered.

In total, 100 words were chosen, uniformly distributed in the following four groups:

1. /a/ in a stressed syllable.
2. /a/ in an unstressed syllable following a palatalised consonant.
3. /a/ in a pretonic syllable following a non-palatalised consonant (first degree of vowel reduction only).
4. /a/ in either a pre-tonic non-initial syllable or a post-tonic non-final syllable.

The corpus was read by three female speakers as a list of carrier sentences containing the target word.[3] As in the case of Catalan, all items were analysed with the Praat+ software and the corresponding waveform displays and broad-band spectrograms were plotted in order to obtain measurements for vowel quality (F1, F2) and duration.

3 RESULTS

The resulting numerical data were processed with the statistical package SPSS. Mean and standard deviation were obtained and comparison tests were applied.

3.1 CATALAN

Our results show that consonantal context does not affect the two target vowels in the same way: while [ə] is significantly affected by its preceding consonant, [a] is not.

F2 values of [ə] increase systematically as the place of articulation of the onset consonant moves backwards (with highest F2 values for palatals). This is not the case for [a], however, where significant differences have not been found.

These preliminary results are summarised in Table 1. The first thing to note here is the considerable decrease in duration of the reduced vowel wrt its stressed counterpart, a fact already observed, e.g., by [8]. Secondly, F2 values of the reduced vowel are considerably much more affected by consonantal context than

[3] Contingencies of informant availability forced us to use female speakers for our experiment and only the data concerning those speakers are considered here; see discussion below, however.

	F1 [a]	F1 [ə]	F2 [a]	F2 [ə]	Dur [a]	Dur [ə]
Dental	713	615	1313	1390	134	70
Alveolar	741	639	1357	1436	138	76
Palatal	693	563	1345	1552	133	74

Table 1: Correlation with consonantal context of F1, F2 (in Hz) and duration (in ms) values for Catalan [a] and [ə].

		Stressed	1st Deg	2nd Deg
	F1	626	332	364
Palatalised	F2	1917	2350	1934
	Dur	113	63	45
	F1	725	685	430
Non-palatalised	F2	1486	1545	1615
	Dur	109	96	60

Table 2: Correlation with consonantal context of F1, F2 (in Hz) and duration (in ms) values of Russian /a/ for stressed contexts and 1st and 2nd degrees of reduction.

those of the full one. This influence is even more striking if we group together the F2 values of vowels preceded by dentals and alveolars—corresponding to the [+anterior] dimension within the class of coronals—with a mean F2 value of 1406 vs. 1552 for palatals—i.e., [−anterior]; this correlation has a high significancy of $0.000(F = 55.66)$. As a general remark, then, we can state that the reduced vowel is more anterior as the place of articulation of the preceding consonant moves backwards.

3.2 RUSSIAN

Consonantal environment is an important factor in the final phonetic realisation of reduced vowels in Russian, but, as our data clearly show, the effect goes well beyond the palatalised/non-palatalised distinction. In fact, a close inspection of the data in Table 2 shows that all vowels fall within the anterior dimension. This is particularly relevant for non-palatalised contexts, as most phonetic descriptions of such vowels present them as mid posterior non-labialised vowels (often phonetically transcribed as [ʌ] for 1st degree and [ɤ] for 2nd degree). Another interesting factor is the effect of duration, especially in palatalised contexts, where the 2nd degree of reduction fails to attain the anteriority observed in the 1st degree and stays closer to that of the stressed counterpart. Finally, even if not shown here, it is relevant to note that a similar correlation between consonantal place of articulation and vowel anteriority as in the Catalan case was observed.

4 DISCUSSION

Our results for Catalan are consistent with experimental evidence offered by other authors. For example, [11] among others give a mean F2 frequency for [a] around 1450Hz and around 1550Hz for [ə]. These values are not too far from our own measurements, where a difference between 100 and 150Hz is also observed, with a mean F2 value for [a] around 1300Hz and around 1400/1450Hz for [ə]. Even though he does not offer any experimental data on this respect, [11] acknowledges that factors related to coarticulatory effects need be taken into account in the phonetic description of Catalan vowels, especially [ə], which, he notes, shows a considerable degree of dispersion wrt F1 and F2 frequencies, a phenomenon that he attributes to the 'weak resistance' of its articulatory configuration to coarticulatory effects.

As for Russian, the data in Table 2 show,[4] wrt the influence of non-palatalised consonants, a gradual increase of F2 frequencies (stressed > 1st degree > 2nd degree) and a gradual decrease of F1 frequencies again in the same direction. These results are not entirely consistent with traditional descriptions of Russian vowels ([12], [13]), where the reduced counterparts of /a/ for both 1st and 2nd degree are presented as mid posterior non-labialised vowels (as noted, often transcribed as [ʌ] and [ɤ]), whereas our results show sounds falling closer to the anterior dimension. We interpret this as an effect of our choice of consonantal environment, but also as a clear indication of the high degree of variability of these reduced vowels in relation to context. Note, moreover, that the true change in vowel quality results only in the transition from 1st to 2nd degree, while no great differences in quality exist between stressed and 1st degree vowels.

With palatalised consonants, on the other hand, we observe clear differences between stressed positions and the 1st degree of reduction. In particular, there is a considerable increase of F2 frequencies (1917Hz vs. 2350Hz) together with a decrease of F1 frequencies (626Hz vs. 332Hz) as a clear indication that the resulting vowel may be interpreted as [i], which may be moreover justified with data for non-reduced [i] in unstressed position: the analysis of a sample from the same corpus indicates that its F1 is around 354Hz and its F2 is around 2379Hz. Our results for the 2nd degree of reduction are a bit surprising: while F1 values stay within a level similar to that of the 1st degree, F2 values are closer to those of the stressed position. In this respect, it may be nevertheless relevant to note that there is also a considerable change in the quantity of the vowel, with a mean of 63ms for 1st degree vowels vs. a mean of 45ms for the 2nd degree. As noted by many authors (e.g., [8]) the degree of formantic reduction is inversely proportional to duration, which leads us to interpret our data for the 2nd degree as a [i] with its formants reduced due, precisely, to a dramatic decrease in duration. Thus VR results in an actual change in the quality of the vowel, whereas the transi-

[4] In order to exclude the possibility that some of these results might be attributed to an effect of choice of informants, we carried out a small control experiment with a male speaker. These data are not significantly different from female speaker data, apart from the expected differences between female and male voices.

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tion from the 1st to the 2nd degree would be a mere process of formantic reduction, which is in agreement with traditional descriptions, which usually associate the same vowel quality to both degrees.

5 CONCLUSIONS

There is a strong tendency in recent analyses of VR ([7], [6] for Russian and [14] for Catalan, all within the framework of Optimality Theory) to specify constraints licensing a fully specified output form in the reduced position or, alternatively, an output vowel without VPlace specifications which eventually surfaces as the unmarked [ə]. Thus, regardless of the approach taken, both Positional Faithfulness ([7], [14]) and Positional Markedness ([6]) analyses predict that the 1st degree reduced variant of /a/ is a low vowel, namely [a] (whence, perhaps, the claim in [14] that Catalan lacks [ə]).

We believe, however, that our preliminary results point in a slightly different direction. First, the clear difference observed in Russian between palatalised vs. non-palatalised environments is already an indication that VR is fairly sensitive to contextual factors, with languages resorting to different strategies in order to determine the final quality of the vowel. Thus, in Russian, the systematic reduction to [i] after palatalised consonants may well be interpreted as a situation in which an underspecified vowel assumes the secondary place of articulation of the preceding consonant, as already suggested, e.g., by [1]. This strategy is not available in the case of non-palatalised consonants (which lack secondary place), however, but, given our results above, it appears that VR in these contexts may show a greater degree of variability than an analysis based on total specification would predict. Thus, and restricting our sample to coronal environments, we have obtained a mid anterior vowel for Russian 2nd degree reduction, which, in our opinion, is far from anything like what a symbol like [ə] would suggest. The same effect is much weaker in Catalan, but still observable.

We are not in a position at the moment to make a full-fledged proposal as to how much underspecification is necessary in reduced vowel positions, partly because this is clearly a matter very much dependent on language-particular issues like, for example, metrical structure and partly because ours is still a very preliminary study which should be extended to cover further data and cases. The general conclusion seems to point, however, in the direction of the need of assuming that VR is, in effect, a process resulting in a vowel which is to a certain degree underspecified for place features, whose final quality is only fully determined at the level of phonetic implementation.

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